Objective measurement and patient-reported evaluation of the nasal airway – is correlation dependent on symptoms or on nasal airflow?

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Abstract

Abstract Background: Evidence showed that the sensation of nasal breathing is related to variations in nasal mucosa temperature produced by airflow. An appropriate nasal airflow is necessary for changing mucosal temperature. Therefore, the correlation between objective measurements of nasal airflow and patient-reported evaluation of nasal breathing should be dependent on the level of nasal airflow. Objectives: To find if the correlation between patient-reported assessment of nasal breathing and objective measurement of nasal airflow is dependent on the severity of symptoms of nasal obstruction or on the level of nasal airflow. Methods: The airway of 79 patients was evaluated using NOSE score and peak nasal inspiratory flow (PNIF). Three subgroups were created based on NOSE and three subgroups were created based on PNIF level to find if correlation was dependent on nasal symptoms or airflow. Results: The mean value of PNIF for the 79 patients was 92.6 l/min (SD 28.1 l/min). The mean NOSE score was 48.4 (SD 24.4). The correlation between PNIF and NOSE was statistically significant (p=0.03), but with a weak association between the two variables (r=-0.248). Evaluation of correlation based on symptoms demonstrated a weak or very weak association in each subgroup (r=-0.250, r=-0.007, r=-0.104). Evaluation of correlation based on nasal airflow demonstrated a very weak association for the subgroups with middle-level and high PNIF values (r=-0.190, r=-0.014), but a moderate association for the subgroup with low PNIF values (r=-0.404). Conclusions: This study demonstrated a weak correlation between NOSE scores and PNIF values in patients non-selected according to symptoms of nasal obstruction or to airflow. It demonstrated that patients with symptoms of nasal obstruction have different levels of nasal airflow and that low nasal airflow prevents the sensation of good nasal breathing. Therefore, patients with symptoms of nasal obstruction may require improving nasal airflow to improve nasal breathing sensation.

Keywords

Nasal airway evaluation, Objective and Patient-Reported evaluation correlation, Correlation based on symptoms, Correlation based on airflow, NOSE, PNIF

Keypoints

- Evidence has shown that the sensation of nasal breathing is related to nasal mucosa temperature variation produced by airflow. An appropriate nasal airflow is necessary for changing mucosal temperature. Therefore, the correlation between objective measurements of nasal airflow and patient-reported evaluation of nasal breathing should be correlated to the level of nasal airflow.
- The airway of 79 patients was evaluated using NOSE score and peak nasal inspiratory flow (PNIF). Three subgroups were created based on NOSE score and three subgroups were created based on PNIF level to find if correlation between NOSE and PNIF was dependent on nasal symptoms or on nasal airflow.

- The mean value of PNIF for the 79 patients was 92.6 l/min (SD 28.1 l/min). The mean NOSE score was 48.4 (SD 24.4). The correlation between PNIF and NOSE was statistically significant (p =0.03), but with a weak association between the two variables (r =-0.248). Evaluation of correlation based on symptoms demonstrated a weak or very weak association in each subgroup (r =-0.250, r =-0.007, r =-0.104). Evaluation of correlation based on nasal airflow demonstrated a very weak association for the subgroups with middle-level and high PNIF values (r =-0.190, r =-0.014), but a moderate association for the subgroup with low PNIF values (r =-0.404).
- This study has shown a weak correlation between objective measurement of nasal airflow and patient-reported evaluation of nasal breathing in patients not selected according to symptoms of nasal obstruction or to the level of nasal airflow.
- This study has shown that a low nasal airflow prevents the sensation of a good nasal breathing. Therefore, patients with symptoms of nasal obstruction and inappropriate nasal airflow may require improving nasal airflow as an essential step to improve nasal breathing sensation.

Introduction

Nasal obstruction is a common complaint of patients undergoing nasal surgery. At the present, several methods are available for assessing the nasal airway. These methods can be divided in two main groups: methods that objectively measure nasal airflow or nasal airway dimensions, and methods based on patient-reported evaluation of nasal breathing.

In theory, objective measurements and patient-reported evaluations of nasal breathing should correlate. If objective methods measure an appropriate nasal airflow then the patient should experience a suitable sensation of good nasal breathing. Therefore, the patient-reported evaluation should reflect that sensation and should correlate with the objective evaluation. However, previous studies have not found statistical correlation between objective measurements of nasal airflow and patient-reported evaluations of nasal breathing (1-10). Some studies have found correlations between nasal resistance and symptoms of nasal obstruction in patients symptomatic for nasal obstruction (11-16), whereas other studies did not find any correlation even in symptomatic patients (18-20). Hence, there is still a great amount of controversy in the literature that deserves further investigation.

A growing body of evidence indicates that the sensation of nasal breathing is more related to variations in nasal mucosa temperature due to the cooling effect of the airstream than to variations in the nasal airflow (8,21-23). According to these studies, an adequate nasal airflow is necessary for providing temperature changes in the nasal mucosa. As such, the correlation between objective measurements of nasal airflow and patient-reported evaluation of nasal breathing should be not only dependent on symptoms of nasal obstruction but should also be dependent on the level of nasal airflow.

The current study had a three-fold purpose: to find if there is correlation between patient-reported assessments of nasal breathing and objective measurements of nasal airflow; to find if this correlation is dependent on the severity of symptoms of nasal obstruction; and to find if this correlation is dependent on the level of nasal airflow.

Methods

A series of 79 consecutive Caucasian patients undergoing rhinoplasty was studied. Nasal airway was evaluated before surgery in each patient of this group as part of the preoperative assessment.

This series consisted of 53 women and 26 men, with ages between 17 and 68 years old (mean 36.2 y/o). Sixty-five were primary cases and 14 were revision rhinoplasty cases. All the primary rhinoplasty cases were looking for an aesthetic improvement of the nose, with 29 also seeking a functional improvement of the nasal airway. For the 14 patients undergoing revision rhinoplasty, there were several different aesthetic indications for the revision surgery, with no functional complaints in none of the patients in this subgroup.

In each patient the NOSE score (Nasal Obstruction Symptom Evaluation) (24) was obtained and peak nasal inspiratory flow (PNIF) (25) was measured before undergoing surgery. The NOSE score was chosen as patient-reported assessment of nasal obstruction symptoms as it is a standardized and validated disease-specific quality of life instrument for measuring nasal obstruction (24). A version validated for the Portuguese language (26) was used in this study. The PNIF was obtained in each patient according to the standard rules for measuring PNIF (25). PNIF was chosen as objective measurement of the nasal airflow as its results not only measure nasal airflow but also correlate with nasal resistance (27). Furthermore, this method, together with rhinomanometry, has been found to strongly reflect both presence and severity of nasal airway obstruction (28).

Three groups of patients were created according to the symptoms of nasal obstruction reported by the patients: patients with NOSE score equal to or less than 35 (N=24), patients with NOSE score between 36 and 64 (N=26) and patients with a NOSE score equal to or higher than 65 (N=29).

Three other groups of patients were created according to the level of nasal airflow: patients with PNIF equal to or less than 70 l/min (N=20), patients with PNIF between 71 l/Min and 109 l/min (N=39) and patients with PNIF equal to or higher than 110 l/min (N=20).

Statistical analysis was made for the total population of this study and for each of the groups created based on NOSE score and on PNIF value. Mean and standard deviations (SD) were obtained for the PNIF and NOSE scores. A multivariable linear regression model was performed in order to investigate the association between the NOSE scores and the PNIF values after adjusting for age and gender of the individuals. The estimated correlation coefficient was obtained for the PNIF score and NOSE value to check the strength of the association between these measurements. The nonparametric Spearman's rank correlation coefficient was employed. A significance level of $\alpha = 0.05$ was used throughout the analysis. The statistical analysis was performed using the R statistical software (29), employing the RStudio environment (30). The graphs were obtained using the R package *ggplot2* (31). The strength of the correlation (r) was valued as very week for$r$ <0.19, week for r between 0.20 and 0.39, moderate for r between 0.40 and 0.59, strong for r between 0.60 and 0.79 and very strong for r between 0.80 and 1 (32).

Results

The mean value of PNIF for this series of 79 patients was 92.6 l/min (SD 28.1 l/min). The mean NOSE score for this group of patients was 48.4 (SD 24.4). The boxplots for these values are displayed in Figure 1 and in Figure 2, respectively.

The scatter plot and the simple regression line of best fit together with 95% confidence bands are shown in Figure 3. It can be observed that there is a decrease in NOSE scores as PNIF values increase, showing a negative correlation. This correlation is statistically significant (p =0.03). The multiple linear regression model demonstrated that for an increase of one unit in NOSE score, PNIF decreases on average 0.25l/min, 95% CI (-0.51, 0.008) p=0.057, when adjusting for age and gender (Table 1). The estimated correlation coefficient between NOSE score and PNIF value was found to be -0.248, which demonstrates a weak association between PNIF value and NOSE score in the group of 79 patients.

In the groups allotted by the NOSE score, the scatter plot and the simple regression line of best fit together with 95% confidence bands are shown in Figure 4. The estimated correlation coefficient for the group of 24 patients with a NOSE score equal to or less than 35 was found to be -0.250, which demonstrates a weak association between PNIF value and NOSE score. In the group of 26 patients with a NOSE score between 36 and 64 the coefficient of correlation between PNIF and NOSE demonstrated a very weak association (r =-0.007). The estimated correlation coefficient for the group of 29 patients with a NOSE score equal to or higher than 65 was found to be -0.104, which demonstrates a very weak association between PNIF value and NOSE score.

In the groups allotted by the PNIF value, the scatter plot and the simple regression line of best fit together with 95% confidence bands are shown in Figure 5.

The estimated correlation coefficient for the group of 20 patients with a PNIF value equal to or less than 70 l/min was found to be -0.404, which demonstrates a moderate association between PNIF value and NOSE score. The estimated correlation coefficient for the group of 39 patients with a PNIF value between 71 l/min and 109 l/min was found to be -0.190, which demonstrates a very weak association between PNIF value and NOSE score. In the group of 20 patients with a PNIF value equal to or higher than 110 l/min there was a very weak association between PNIF value and NOSE score (r =-0.014).

Discussion

This study found a statistically significant but weak correlation between patient-reported evaluation of nasal breathing and objective measurement of nasal airflow in patients not selected according to symptoms of nasal obstruction or to the level of nasal airflow. A weak or very weak correlation between patient-reported evaluation of nasal breathing and objective measurement of nasal airflow was found in groups of patients selected according to symptoms of nasal obstruction.

The current investigation supports that a moderate to high nasal airflow does not necessarily lead to a subjective sensation of a good nasal breathing, according to the widespread NOSE scores amongst patients with moderate to high values of PNIF. Moreover, our results also suggest that a low nasal airflow prevents the sensation of a good nasal breathing to happen.

It is well established, according to Poiseuille‘s Law, that airway resistance is inversely proportional to the 4^{th} power of the radius of the space passed through. Yet, several reasons may explain why a wide nasal airway, as measured by acoustic rhinometry or by the cross-section dimension on imaging techniques of the nasal airway, may not necessarily correspond to a good nasal airflow. Firstly, a nasal airway too wide can prevent the negative pressure necessary to inhale air to be generated. Secondly, an overly wide nasal cavity may decrease laminar airflow and significantly increase turbulent airflow, which may disturb nasal breathing (33-35). And, thirdly, the dimensions of the nasal airway have no relation to the resilience of the nasal cavity walls, which is necessary to withstand the negative pressure generated during inspiration.

Therefore, a wide nasal airway is not the sole factor for obtaining a suitable and pleasant airflow. Objective measurements of the nasal airflow do not always correlate with the subjective sensation of nasal breathing, as reported in our study as well as in others‘ (1-10), suggesting that factors other than an appropriate airflow are important in determining the subjective sensation of a suitable nasal breathing. Several reports have found that the sensation of nasal breathing is more related to variations in nasal mucosa temperature due to the cooling effect of the airstream than to the level of nasal airflow (8,21-23). The sensation of nasal breathing is delivered to the brain by non-myelinated trigeminal afferent fibers originating in receptors located in the nasal mucosa (36-38). In this system, the target thermoreceptor in the nasal mucosa has been identified as the non-selective voltage-dependent cation channel transient receptor potential melastin family member 8 (TRPM8) (39,40). These thermoreceptors, which are distributed throughout the mucosa of the nasal cavity (41,42) and mainly in the anterior part of the nasal airway (37), are sensitive to temperature changes in the nasal mucosa caused by the airstream. Mucosal cooling directly excites these receptors, as the airstream passes through the nasal cavity, triggering trigeminal afferent stimulation and providing perception of nasal breathing (21-23,38,43,44).

Therefore, for an appropriate sensation of nasal breathing a nasal cavity wide enough to allow the airstream to cool the nasal mucosa is necessary. Bailey *et al* (44) found a

negative correlation between nasal resistance and the degree of mucosal cooling. But also an adequate nasal airflow is necessary for providing temperature changes in the nasal mucosa. Lindemann *et al* (45) found that the increased nasal airflow during deep breathing was associated with greater oscillations in nasal mucosal temperature and greater sensation of airflow than in quiet resting breathing.

The mean value of PNIF in our series was noticeably lower than the mean values that have previously been published in series with healthy populations (26,46-49). This probably reflects the fact that our study was performed in rhinoplasty-seeking patients, some complaining of nasal obstruction, and not in a healthy population, as the mean NOSE score of 48.4 (SD 24.4) in our series indicates.

Previous researchers (11-16) have found correlation between patient-reported assessment of the nasal airway and objective measurements of nasal airway resistance or of nasal airflow to be dependent on the severity of symptoms of nasal obstruction. Our investigation focused on groups of patients that were created in accordance to the degree of nasal obstruction as reflected by the NOSE score, and found that this correlation was weak or very weak in each of these subgroups (r =-0.250, r =-0.007, r =-0.104). These findings are in line with the results of other publications (17-20). Our study shows that patients with symptoms of nasal obstruction have different degrees of nasal airflow, which favors that symptoms of nasal obstruction are not solely determined by nasal airflow.

Based on the mean value of PNIF of our study, we split our series of 79 patients into three groups of patients, with low, moderate or high PNIF values, and tried to find if correlation between patient-reported assessment of the nasal airway and objective measurements of nasal airflow was dependent on the degree of nasal airflow. This correlation was very weak for patients with moderate or high nasal airflow value (r =-0.190, r =-0.014). For patients with low PNIF value, however, there was a moderate correlation between nasal airflow and the NOSE score (r =-0.404), suggesting that a low nasal airflow prevents a good sensation of nasal breathing. These results are in favor that an adequate nasal airflow may or may not be associated with sensation of good nasal breathing, consistent with the assumption that factors other than airflow play an important role on providing sensation of nasal breathing. Our findings also suggest that an inadequate nasal airflow will negatively act on the patient´s sensation of a suitable nasal breathing, probably due to insufficient nasal mucosal cooling. This finding has important outcomes in the way patients with nasal obstruction should be addressed. If patients with symptoms of nasal obstruction have inadequate nasal airflow, then improving the airflow is an essential step towards improving nasal breathing sensation.

This study was accomplished in a non-homogeneous group of patients, with predominance of female patients. Also, the groups of patients created based on the NOSE score and on the PNIF level were relatively small in number, which may have influenced the low coefficients of correlation in some of these groups. Likewise, all the patients included in the series were rhinoplasty-seeking patients, and not randomly selected individuals. This may have interfered on the difference between the mean value of PNIF of this series when compared to previously published series in healthy populations. Moreover, some of the patients included in the study had already been submitted to nasal surgery, which may have changed the perception of nasal breathing reflected by the NOSE score and nasal airflow reflected by PNIF value. Nevertheless, none of the patients undergoing revision rhinoplasty had complaints of nasal obstruction. Lastly, the NOSE score is currently the most frequently used patient-reported assessment of symptoms of nasal obstruction, though having initially been developed as a patient reported outcome measurement of the effect of septoplasty on nasal obstruction (24).

Conclusion

This study has shown a weak correlation between objective measurement of nasal airflow and patient-reported evaluation of nasal breathing in patients not selected according to symptoms of nasal obstruction or to the level of nasal airflow. It has also been demonstrated that patients with symptoms of nasal obstruction have different degrees of nasal airflow, indicating that the sensation of nasal obstruction is not solely determined by nasal airflow.

The findings of this study also suggest that a low nasal airflow prevents the sensation of a good nasal breathing. According to this, patients with symptoms of nasal obstruction and inappropriate nasal airflow may require improving nasal airflow as an essential step towards achieving an optimal functional result.

Conflict of Interests Declaration:

The Authors declare that they have no conflicts of interest

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Tables

	Coefficients Estimates	SE	p-value
Intercept	86.588	11.751	<0.001
NOSE -	0.249	0.129	0.057
Age	0.457	0.274	0.099

	Coefficients Estimates	SE	p-value
Sex (male)	4.567	6.574	0.486

Table 1: Estimated regression coefficients, standard error (SE) and p-values of a multiple linear regression model

Legends of Figures

Figure 1: Boxplot for the registered PNIF values (l/min) (Mean 92.6 l/min SD 28.1 l/min)

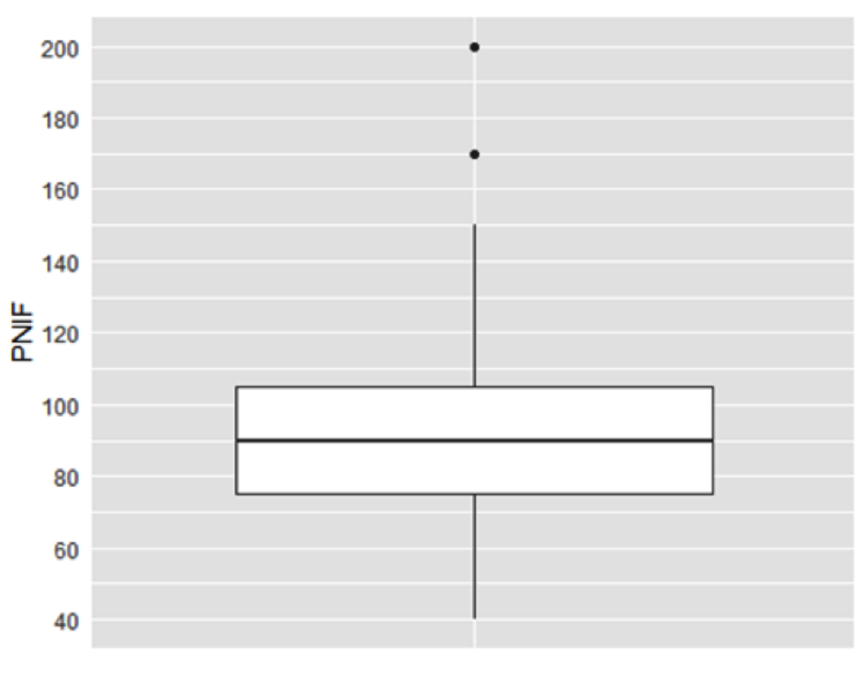
Figure 2: Boxplot for the registered NOSE scores

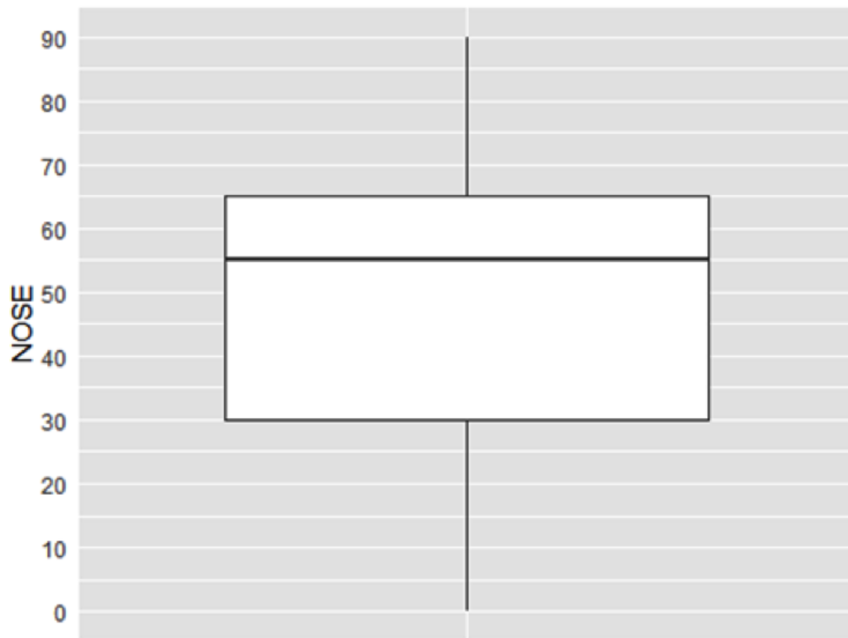
(Mean 48.4 SD 24.4)

Figure 3: Scatter plot and simple regression line of best fit together with 95% confidence bands between PNIF values and NOSE scores

Figure 4: Scatter plot and simple regression lines of best fit together with 95% confidence bands between PNIF and NOSE for each subgroup of patients based on NOSE score

Figure 5: Scatter plot and simple regression lines of best fit together with 95% confidence bands between PNIF and NOSE for each subgroup of patients based on PNIF value

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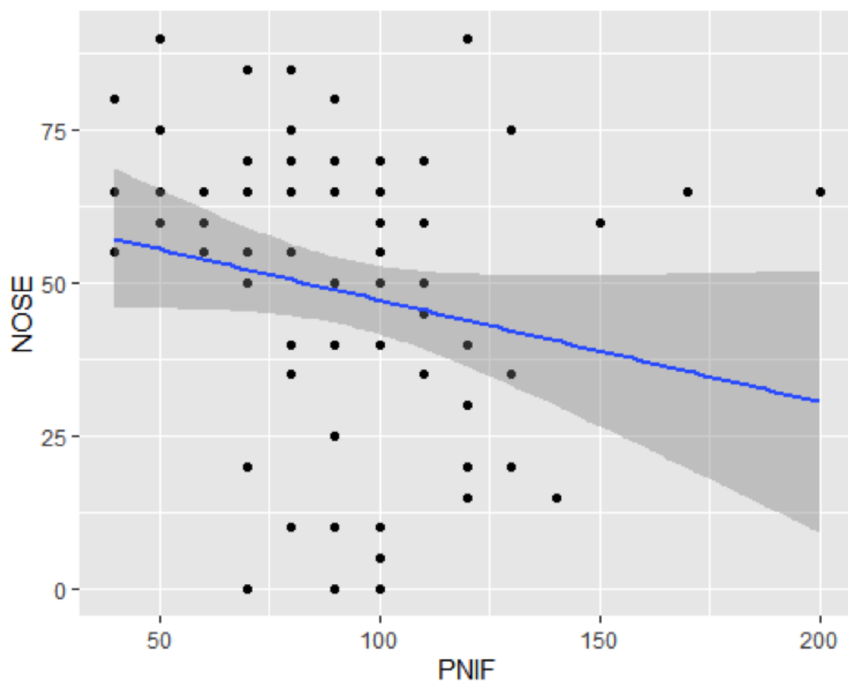
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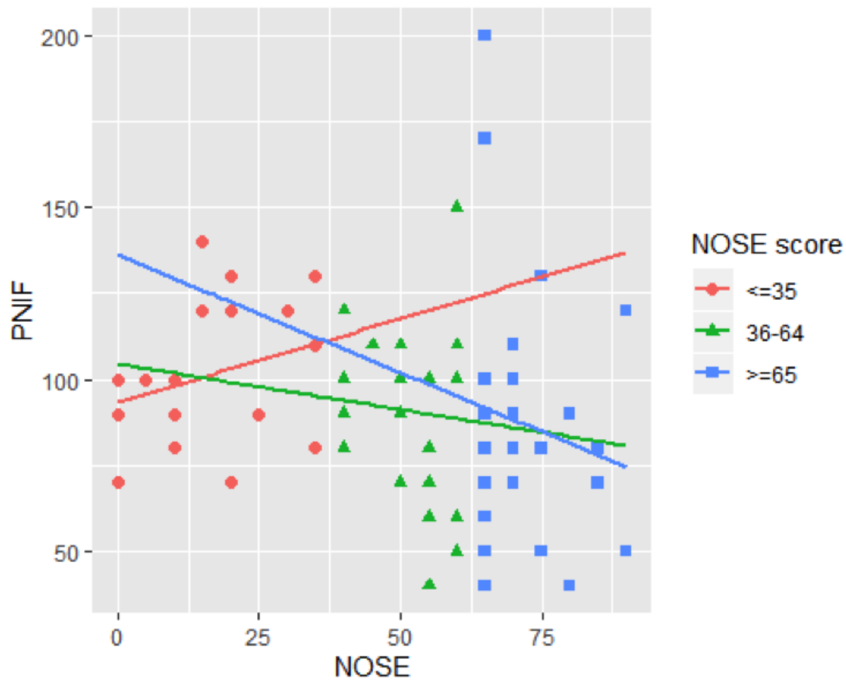

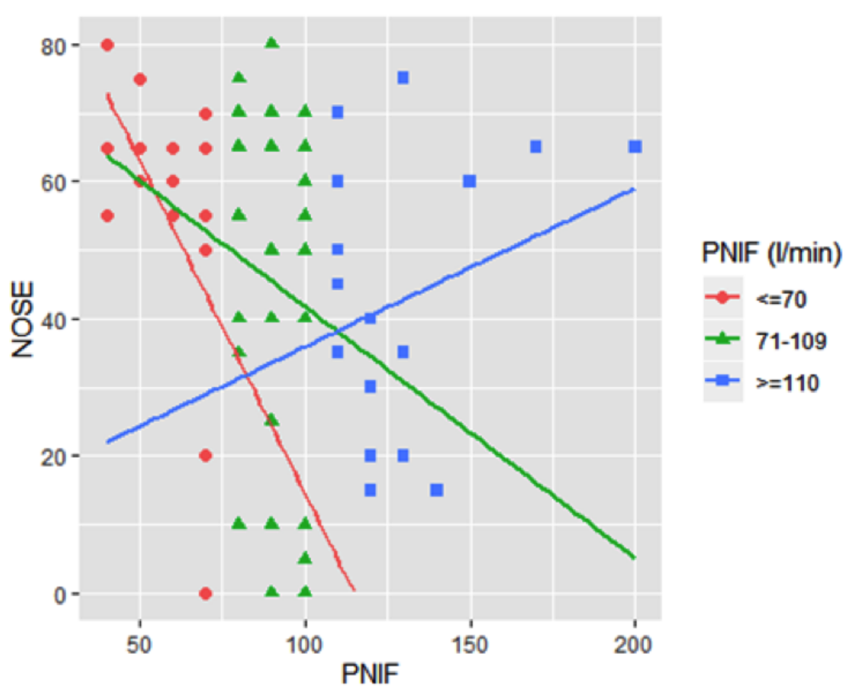

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Table 1.pdf available at https://authorea.com/users/361727/articles/483085-objective-measurement-and-patient-reported-evaluation-of-the-nasal-airway-is-correlation-dependent-on-symptoms-or-on-nasal-airflow